1995

Summary of Research 1995, Department of Meteorology

Faculty of the Department of Meteorology, Naval Postgraduate School

Office of the Associate Provost and Dean of Research, Naval Postgraduate School.

http://hdl.handle.net/10945/39212

NPS-09-96-008

Naval Postgraduate School
Monterey, California 93943-5138

SUMMARY OF RESEARCH 1995

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Monterey, California

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REPORT DOCUMENTATION PAGE

Form approved

OMB No 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	August 1996	Summary Report, 1 January 1995 - 31 December 1995

4. TITLE AND SUBTITLE
Summary of Research 1995, Department of Meteorology

5. FUNDING

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

NPS-09-96-008

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Naval Postgraduate School
Monterey, CA 93943-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

The views expressed in this report are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

A

13. ABSTRACT (Maximum 200 words.)

This report contains 32 summaries of research projects in the Department of Meteorology which were carried out under funding of the Naval Postgraduate School Research Program. A list of recent publications is also included which consists of conference presentations and publications, books, contributions to books, published journal papers, and technical reports.

14. SUBJECT TERMS

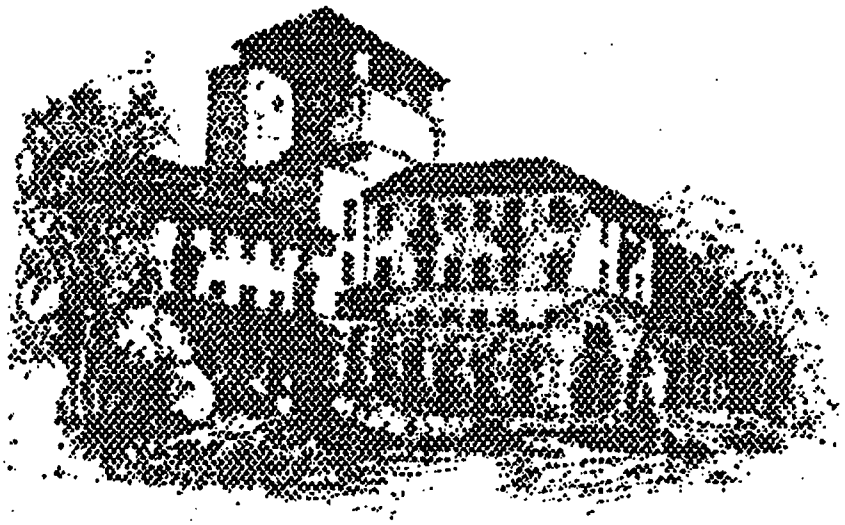
15. NUMBER OF PAGES
53

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to provide advanced professional studies at the graduate level for military officers and defense officials from all services and other nations. The School's focus is to increase the combat effectiveness of the armed forces of the United States by providing quality education which supports the unique needs of the defense establishment.



Introduction

Research is an integral part of graduate education. At the Naval Postgraduate School (NPS), the goals of research are to:

- Provide a meaningful, high quality, capstone learning experience for our students.
- Keep faculty on the leading edge of advances in defense-related science, technology, managment and policy to ensure that the latest information is incorporated into NPS courses and curricula.
- Apply faculty and student knowledge to enhance Navy/DoD operational effectiveness.

Pursuit of these goals increases the technical and managerial capability of the officer corps to keep pace with an increasingly complex defense posture in today's world.

The overall research program at NPS has two funded components:

- The Direct Funded Research (DFR) Program provides internal funding from the School's operating budget to stimulate innovative research ideas of benefit to the DoN and may be used for cost-sharing with reimbursable research efforts. This funding ensures, in particular, that all Navy-sponsored NPS curricula are equitably supported, that new faculty are provided an opportunity to establish a research program of importance to DoN/DoD and other national security interests, and that faculty and students from across the campus are encouraged to interact with one another.
- The Reimbursable Research (RR) Program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policy makers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. This ensures that NPS research remains highly regarded by academic peers and government officials and fosters a closer relationship between NPS and other outside organizations.

The two research programs are complementary and ensure that the overall research program is flexible, responsive, balanced and supportive of the unique needs of the military.

All research projects, both reimbursable and direct funded, support the School's research mission:

- To develop an overall research investment strategy that ensures a high quality, creative learning experience for NPS graduate students.
- To encourage faculty and student pursuit of new discoveries and applications which enhance the long term effectiveness of the armed forces.
- To stimulate interactions between NPS faculty and a wide variety of potential research sponsors (Government, Universities, Private Industry).
- To publicize (both internally and externally) significant achievements of the NPS research program and market NPS research capabilities.
- To foster synergy and force multiplication with Navy/DoD commands and laboratories to increase the potential for successful research and development programs

The Meteorology Department provides graduate-level instruction in the science of meteorology and its application in support of military operations. To maintain expertise and provide support to student theses, the faculty perform research in the Navy relevant areas of synoptic and dynamic meteorology, remote sensing, numerical modeling, tropical meteorology, boundary layer meteorology and environmental effects.

Over 30 years ago, NPS was responsible for the establishment and flourishing of a Navy operational command on its campus. In 1959, the Naval Oceanographic Command (formerly the Naval Weather Command) moved its numerical prediction unit from Suitland, Maryland, where it was part of a joint National (civilian), Navy and Air Force Weather Services organization, to Monterey as a new operational command: the Fleet Numerical Weather Central (now called the FNMOC). The move to Monterey was prompted by the special requirements of the Navy because of its ocean operations which were not adequately met in the joint civilian-military center. The Navy chose to move FNMOC to Monterey to take advantage of the presence of the Naval Postgraduate School with its large assembly of science faculty who are intimately familiar with Navy operational problems in meteorology and oceanography. For similar reasons, the Navy Environmental Prediction Research Facility (NEPERF, now the Marine Meteorology Division of NRL, or NRL-West), moved to Monterey in 1971 from Norfolk, Virginia, a further augmentation of meteorological and oceanographic scientists in Monterey, making it the center of Naval environmental science.

The consequences of these moves are the substantial involvement of NPS faculty in research projects at NRL-Monterey and the enhancement of operational capabilities at FNMOC. Furthermore, personnel from the latter two organizations are able to take advanced courses at NPS, and officer-student at NPS can engage in thesis research on "real-life" applications relating environmental parameters to Naval operations.

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METEOROLOGY

The following research summaries describe projects which were carried out under the direction of faculty members in the Department of Meteorology during FY95. The projects were carried out by a dozen Principal Investigators with funding from eleven (11) different sponsors. The projects range from very applied research for the operational Navy and National Weather Service to basic theoretical studies sponsored by the National Science Foundation, Office of Naval Research, and the National Aeronautical and Space Administration. Major research areas in the department include tropical cyclones, coastal meteorology, synoptic and mesoscale meteorology, boundary layer meteorology, remote sensing, electromagnetic and optical propagation in the atmosphere, atmospheric aerosols (their sources and interaction with clouds), numerical atmosphere and ocean modeling, tropical meteorology and air-sea interaction. All of these research efforts involve our officer students whose contributions are documented in their M.S. theses or Ph.D. dissertations.

METEOROLOGY

Meteorology and Oceanography Sciences Laboratories

NPS has an active seagoing research program in oceanography, meteorology, and environmental acoustics. Instrumentation aboard the R/V POINT SUR includes CTD (conductivity, temperature, depth) and expendable bathythermograph (XBT) systems, an acoustic Doppler velocity profiler (ADVP), an acoustic (atmospheric) sounder, a micrometeorologically instrumented mast, continuous underway measurements of conductivity and temperature at 2 m, position, (including Global Positioning System and Loran receivers) and surface atmospheric variables, and a contemporary digital data-acquisition system. The Oceanography Department maintains a suite of modern current-measuring equipment for experimental use including Aanderaa current meters and electromagnetic current meters, acoustic Doppler profilers, and acoustic releases; drifting buoys of various types are also available. The micrometeorological instrumentation suites are used on aircraft and abroad ship. Other facilities include analysis laboratories for mesoscale ocean prediction, ocean turbulence, nearshore processes, satellite remote sensing, and numerical meteorology and oceanography. Access is also provided to supercomputer facilities at NCAR, the Naval Research Laboratory, and the Naval Oceanographic Office. Synoptic laboratory facilities include access to both National Meteorological Center (NMC) and Fleet Numerical Meteorology and Oceanography Center (FNMOC) numerical analysis and prognoses, real-time satellite data, and surface and upper-air observation capability. Acoustic transceivers, a listening array off Point Sur, and associated analysis facilities are also available.

The Meteorology Department's new Marine Atmospheric Measurements Laboratory features state-of-the-art instrumentation for calibration work and for probing the atmosphere with both in situ and remote-sensing devices. The laboratory features meteorological ground stations, 405 and 915 MHZ doppler-radar wind profilers, a rawinsonde system, a SODAR system, and a fully instrumented surface weather station. A major center for interdisciplinary remotely piloted aircraft studies (CIRPAS) is currently being established with two field programs planned for 1996. An Interactive Digital Environmental Analysis Laboratory (IDEA Lab) provides modern computer technology and real-time data bases for graduate instruction and research in synoptic oceanography and meteorology, remote-sensing applications, and numerical weather prediction. The IDEA Lab consists of 16 UNIX workstations that support numerical computation, graphics, image analysis, and visualization. Real-time local data from the Measurements Laboratory; global data acquired through UNIDATA, DMSP, and GOES satellite data; and analysis and forecast products from NMC, FNOC, and ECMWF are available for analysis and display in a modern Synoptic Laboratory with large-screen video/animation capability.

FY95 REIMBURSABLE PROGRAM
Department of Meteorology

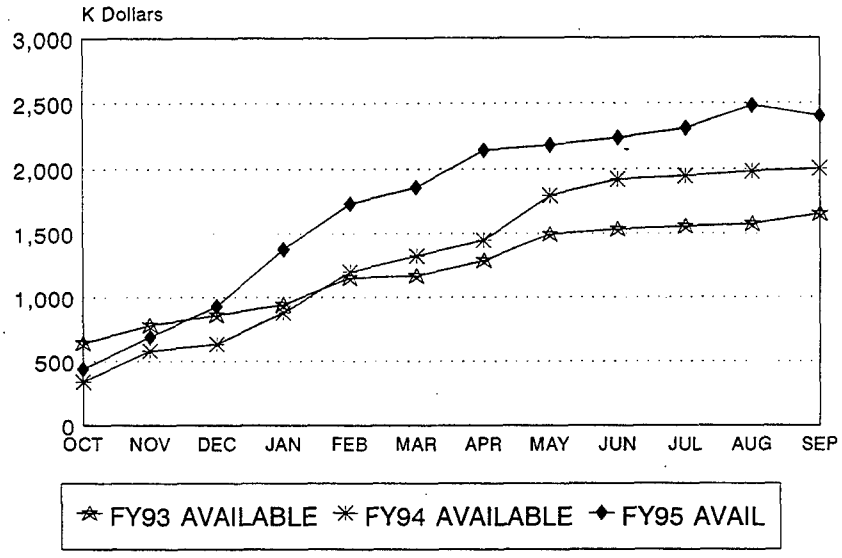

Figure 1. Reimbursable Funds Available by Fiscal Year.
This graph shows the amount of reimbursable funding available to the department. Dollar amounts include research and academic reimbursable activities.

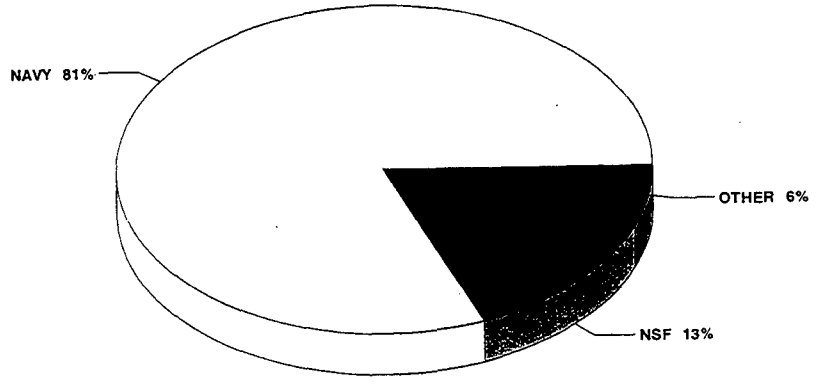

Figure 2. FY95 Reimbursable Sponsor Profile.

METEOROLOGY

TROPICAL CYCLONE MOTION

Lester E. Carr, III, Assistant Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: The principal objective of this continuing research project is to develop a comprehensive and meteorologically sound methodological and conceptual framework by which tropical cyclone (TC) forecasters may: (i) insightfully interpret the TC motion ramifications of evolving global model fields; and, (ii) anticipate errors in the tropical cyclone forecast tracks provided by the Navy Operational Global Atmospheric Prediction System (NOGAPS) and by other objective track forecast aids that depend on the NOGAPS numerical model. This methodological framework has been termed the Systematic and Integrated Approach to Tropical Cyclone Track Forecasting (hereafter Systematic Approach), and is being developed in collaboration with R. L. Elsberry. An expected long-term result of this project is to achieve an overall improvement in tropical cyclone track forecast accuracy by: (i) reducing the incidence of excessively high track forecast errors (aka "busts"); and, (ii) improving the temporal consistency of track forecasts.

SUMMARY: In addition to the strategic formulation of the overall Systematic Approach concept, particular emphasis and care have been given to formulation of the key meteorological knowledge base of TC-Environment conceptual models, and its initial testing in the western North Pacific basin (WESTPAC). Regular visits have been made to the Joint Typhoon Warning Center (JTWC) to dialogue with forecasters and obtain crucial feedback on designing the optimum set of conceptual models. A technical report (Carr *et al.* 1995) documents important insights gained and refinements made to the meteorological knowledge base arising from a five-year environment structure climatology, and the results of a reproducibility study that tested the effectiveness of the knowledge base under quasi-operational conditions. One paper addressing the motion implications of tropical cyclone interaction with monsoon gyres (Carr and Elsberry 1995) has been published. A tropical cyclone wind distribution model played a key role in the interactive analysis of vertical wind shear effects on tropical cyclone development by Jeffries (1995) and Jeffries *et al.* (1995). Similarly, some of the processes associated with the North-Oriented Pattern environment structure model involved a single large tropical cyclone have been included in study of WESTPAC tropical wave patterns by Chang *et al.* (1995).

PUBLICATIONS:

Carr, L.E. and Elsberry, R. L., "Monsoonal Interactions Leading to Sudden Tropical Cyclone Track Changes," Monthly Weather Review, Vol. 123, pp. 265-289, 1995.

Carr, L.E., Boothe, M.A., White, S.R., Kent, C. S., and Elsberry, R. L., "Systematic and Integrated Approach to Tropical Cyclone Track Forecasting. Part II. Climatology, Reproducibility, and Refinement of Meteorological Knowledge Base," Naval Postgraduate School Technical Report, NPS-MR-95-001, 1995.

CONFERENCE PRESENTATIONS:

Boothe, M.A., Carr, L.E., Kent, C.S., White, S.R., and Elsberry, R.L., "Application of the Systematic Approach to Track Forecasting -- Testing the Synoptic Pattern-Region Evaluations," Preprints, 21st Conference Hurricanes Tropical Meteorology, American Meteorological Society, Boston, MA, pp. 47-49, 1995.

Carr, L.E. and Elsberry, R.L., "Overview of the Systematic Approach to Tropical Cyclone Track Forecasting," Preprints, 21st Conference Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA, pp. 44-46, 1995.

Carr, L.E. and Elsberry, R.L., "Development of Operationally Relevant Knowledge Bases for Systematic Approach to Tropical Cyclone Track Forecasting," 1995 Tropical Cyclone Conference, Tokyo, Japan, February 1995.

Carr, L.E. and Elsberry, R. L., "Application of the Systematic Approach to Adjust for Systematic Errors in the Objective Guidance," 1995 Tropical Cyclone Conference, Tokyo, Japan, February 1995.

Elsberry, R.L. and Carr, L.E., "Effects of Large-scale Environmental Fields on Tropical Cyclone Motion," Fourth Technical Conference on SPECTRUM, Tsukuba, Japan, November 1995.

Elsberry, R.L. and Carr, L.E., "Overview of the Systematic Approach to Tropical Cyclone Track Forecasting being Tested at JTWC, Guam," ESCAP/WMO Typhoon Committee Meeting, Kuala Lumpur, Malaysia, December 1995.

THESES DIRECTED:

Jeffries, R.A., "Evaluation of an Interactive Regional Wind Analysis Procedure for the Tropics," Master's Thesis, September 1995.

Kent, C.S.T., "Systematic and Integrated Approach to Tropical Cyclone Track Forecasting in the North Atlantic," Master's Thesis, December 1995.

White, S.R., "Systematic and Integrated Approach to Tropical Cyclone Track Forecasting in the Eastern and Central North Pacific," Master's Thesis, December 1995.

OTHER:

Chang, C.-P., Chen, J.-M., Harr, P.A., and Carr, L.E., "Northwestward-propagating Wave Patterns over the Tropical Western North Pacific during Summer," submitted to Monthly Weather Review.

DOD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Tropical cyclones, tropical cyclone motion, tropical cyclone forecasting

TROPICAL AND MONSOON STUDIES

Chih-Pei Chang, Professor
Roger T. Williams, Professor
Department of Meteorology
Sponsor: National Science Foundation

OBJECTIVE: This is a continuing project to study the structure and properties of large-scale and frontal motions in the tropical and Asian monsoon regions.

SUMMARY: The research consisted of both observational and theoretical studies. The observational studies develop and use principal component analysis techniques to determine the structure of these motion systems from global gridded data. The theoretical studies are done by numerical model simulations. A new technique of searching for correlated motion patterns was developed. This technique allows the identification of patterns from more than two fields. This and traditional methods revealed the effect of large island terrain on tropical cyclone structure and motion deflection due to pressure forces, a northwestward propagating disturbance that is associated with tropical cyclones in the western North Pacific, and that moist midlatitude fronts moving into the tropics are important in the development of summer monsoon in the South China Sea. In the theoretical study, the terrain effect on tropical cyclone motions is simulated in a numerical model, and the mechanisms of moist midlatitude weather system were studied, isolating the effects of the mean wind and the terrain.

PUBLICATIONS:

Chang, C.-P. and Zambresky, L., "Observed and Navy Global Model Climatologies of Synoptic Disturbances Over the Tropical Western Pacific During Northern Winter 1991-92: A Spectral Analysis," Monthly Weather Review, Vol. 123, pp. 430-443, 1995.

Peng, M., Chen, D., Chang, S., Chang, C.-P., and Jeng, B., "Improvement of Numerical Prediction of Typhoon Tracks in the Western North Pacific Near Taiwan," Weather and Forecasting, Vol. 10, pp. 411-424, 1995.

Chang, C.-P. and Chen, G.T., "Tropical Circulations Associated with Southwest Monsoon Onset and Westerly Surges Over the South China Sea," Monthly Weather Review, Vol. 123, pp. 3254-3267, 1995.

Peng, M.S., Li, S.-W., Chang, S., and Williams, R.T., "Flow Over Mountains: Coriolis Force, Transient Troughs and Three Dimensionality," Quarterly Journal Royal Meteorological Society, Vol. 121, pp. 593-613, 1995.

CONFERENCE PRESENTATION:

Chang, C.P., Chen, J.M., and Cardenas, J., "Intraseasonal Oscillations in the Meridional Wind Component During Summer 1989-1991," Session on Monsoon Meteorology, 14th Pacific Science Congress, Beijing, China, 6-11 June 1995.

THESES DIRECTED:

Jarvis, J.R., "Analysis of the East Asian Cold Surge Using a 15-year Navy Data Set," Master's Thesis, March 1995.

Cheng, C.C., "A 15-year Climatology of Synoptic Disturbances Over Tropical Northwestern Pacific During Summer," Master's Thesis, March 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Tropical meteorology, monsoons, typhoons, tropical waves

MONSOON DISTURBANCES OVER THE CHINA SEAS

Chih-Pei Chang, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: This research is to use operational Naval regional models to study the development of the southwest monsoon over the South China Sea and East China Sea, and its effects on weather disturbances over Southeast and East Asia.

SUMMARY: In order to prepare for modeling simulations, two pilot observational studies were carried out. The first is a study of the development of southwest monsoon flow in May and June using 1981-1986 ECMWF data and the Satellite Outgoing Longwave Radiation (OLR) data. It focused on tropical circulations associated with the development of low-level westerlies during monsoon onsets in May and southwesterly surges in June. Composites of different fields indicate that both events occur with the approach of a midlatitude trough/front system. The front establishes a quasi-stationary position near the southern China coast, and allows an acceleration of southwesterlies to its south and a sustained transport of moisture from the Indochina Peninsula and the warm sea surface of the South China Sea.

Time change fields during the monsoon onsets and the June surges reveal interesting teleconnection-like patterns in the tropics in both hemispheres. During the May onsets, the arrival of the midlatitude trough/front appears to lead to a southwestward extension of a cyclogenesis zone into the equatorial Indian Ocean. Along this zone, cyclonic vortices develop over the Andaman Sea, the Bay of Bengal, and perhaps the southern equatorial Indian Ocean, and increased deep convection is indicated by the OLR composites. During the June surges, a pair of anticyclones develop straddling the equator at the longitudes of Indochina. This anticyclonic couplet is associated with decreased deep convection in the OLR field and propagates westward to dominate the flow changes over the Bay of Bengal and the southern Indian

Ocean. The steady 4-5 m/s westward speed and near-perfect symmetry with respect to the equator indicate the possibility of an equatorial Rossby wave generation in conjunction with the June westerly surges in the northern South China Sea. These results are published in Chang and Chen (1995).

The second study is a collaborative work with Professor Peter Chu of the NPS Oceanography Department to study the time and spatial sea (SST) characteristics in the South China Sea using the Navy's MOODS data for March-June 1966. The large variability in the spatial and time distribution and the quality of the MOODS observations make it necessary to perform hand analysis on 10-day maps. Analysis is completed for the spring and fall of 1966. The results show the development of a warm pool in the northern-central South China Sea off the Luzon Island during May. The warm pool has maximum temperature 29°-30°C, and is separated from the rapid seasonal warming region of the southern South China Sea which reaches 30°C in May over a larger area. The warm pool vanishes after late May 1966, when the summer monsoon is well established. By comparing the climatological surface wind field over the same area, we hypothesized that the subtropical high influencing the South China Sea caused an anticyclonic Ekman downwelling in the spring that reduces or prevents the upwelling of cold water from the deep sea and contributes to the warming. This warm pool may help the development of convection over the northern South China Sea and southern China by supplying increased sensible and latent heat fluxes to the southwesterlies. As the monsoon develops in late spring and early summer, the western edge of the subtropical high retreats eastward to the western Pacific, and the downwelling effect diminishes. This allows the upwelling and, together with other components of the monsoon such as convective cloud and rainfall, the local SST over the central South China Sea no longer maintains a warm pool identity.

The above hypothesis offers a scenario of the air-sea interaction during the development of the southwest monsoon over the South China Sea. However, the data over other years need to be analyzed to evaluate whether the warm pool phenomenon also exist. A preliminary objective analysis using the empirical orthogonal function (EOF) method indicates that there is a fairly large interannual variation in the warm pool appearance, thus detailed case studies of the other years will be also required. The 1966 case study was reported in the CLIVAR-GOALS monsoon workshop (Chu and Chang, 1995) and international SCSMEX Scientific Workshop (Chu and Chang, 1995). The preliminary EOF study showing the large interannual variations is reported in an NPS M.S. thesis (Tseng, 1995).

Towards the end of the year work was started to consider computer platforms to run the operational NORAPS model for the case studies of the southwest monsoon.

PUBLICATION:

Chang, C. P. and Chen, G.T., " Tropical Circulations Associated with Southwest Monsoon Onset and Westerly Surges Over the South China Sea," Monthly Weather Review, Vol. 123, pp. 3254-3267, 1995.

CONFERENCE PRESENTATIONS:

Chang, C.P., Chen, J.M., and Cardenas, J., "Intraseasonal Oscillations in the Meridional Wind Component During Summer 1989-1991," Session on Monsoon Meteorology, 14th Pacific Science Congress, Beijing, China, 6-11 June 1995.

Chu, P. and Chang, C.P., "A case study of the South China Sea warm pool," CLIVAR-GOALS Workshop on Asian-Australian Monsoon Meteorology and Oceanography, Melbourne, Australia, 10-12 April 1995.

Chu, P. and Chang, C.P., "South China Sea Warm Pool and Monsoon Development," International SCSMEX Workshop, Beijing, China, 5 June 1995.

THESIS DIRECTED:

Tseng, H.C., "EOF Analysis of the South China Sea Surface Temperature During Boreal Spring," Master's Thesis, September 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Tropical meteorology, monsoons, China Seas

EVALUATION OF TROPICAL SYNOPTIC SCALE ANALYSIS AND PREDICTION BY NAVY GLOBAL MODEL

Chih-Pei Chang, Professor
Department of Meteorology
Sponsor: Naval Postgraduate School

OBJECTIVE: This project continues to analyze the tropical motions systems contained in the analysis and forecast fields of the Navy's global numerical weather prediction model.

SUMMARY: The radiosonde and Navy global model's analysis and 48 h forecast fields were analyzed using cross-spectral method, to study the ability of the model in representing synoptic-scale disturbances over the equatorial western and central Pacific during northern winter. In the westernmost Pacific, the vertical structure based on radiosonde data shows a eastward tilt with height in the lower troposphere, which is opposite to the typical summer structure previously observed. This contrast may be explained by the reversal in the vertical zonal wind shear due to the change from the Asian summer monsoon to Asian winter monsoon, and is similar to the variations between contrasting ENSO phases. Although the structure variation is reproduced by the analysis field, comparison of the forecast field and radiosonde results shows that the former appear to generate a downstream propagation of central Pacific waves into area where the disturbances are not observed by radiosondes.

PUBLICATION:

Chang, C.-P. and Zambresky, L., "Observed and Navy Global Model Climatologies of Synoptic Disturbances Over the Tropical Western Pacific During Northern Winter 1991-92: A Spectral Analysis," Monthly Weather Review, Vol. 123, pp. 430-443, 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Tropical meteorology, numerical weather, prediction, global model

REMOTE SENSING OF ATMOSPHERIC REFRACTION IN COASTAL REGION (VOCAR)

Kenneth L. Davidson, Professor
Carlyle H. Wash, Professor
Department of Meteorology
Sponsor: Naval Command Control and Ocean Surveillance Center, Research and Development Division

OBJECTIVE: To provide the Navy with the capability to obtain remote sensing derived estimates of coastal region refractive conditions, including mixed-layer depth, near-surface moisture variations, and wind influenced evaporation duct conditions.

SUMMARY: A modified algorithm for satellite sensor multispectral estimates of the marine atmospheric boundary layer depths was applied to VOCAR periods in which radiosondes were launched a seven locations within 30 minutes of the NOAA satellite pass. For clear-sky cases the method worked well, within 15%, even when there is significant amounts of mid-tropospheric water vapor. Atmospheric surface layer and radiosonde data related to refraction properties were collected on the R/V Point Sur during May and August 1995 periods. Special collection and archiving procedures have been carried out on satellite data from both NOAA polar orbiters in order to evaluate satellite sensor retrieval of boundary layer both cloudy (IR-duct) and clear (multispectral) conditions. Performed shipboard and buoy measurements of atmospheric surface- and mixed- layers off SW coast of Norway in conjunction with ERS-1/2 calibration/validation campaign; from 12 September to 1 October 1995.

PUBLICATIONS:

Davidson, K.L. and Wash, C.H., "Remote Measurement of Atmospheric Refraction Conditions in the Coastal Region," AGARD-CP-557, 4.1 - 4.6, 1995.

Wash, C. H., Davidson, K.L., and Jordan, M. S., "Remote Measurement of Coastal Marine Atmospheric Boundary Layer (MABL) Features," Proceedings, IGARSS'95, Florence, Italy, pp. 2089-2091, 10-14 July 1995.

Wash, C.H., Davidson, K.L., and Jordan, M.S. "Remote Measurement of the Coastal Marine Atmospheric Boundary Layer," Proceedings, OCEANS'95, San Diego, CA, pp. 79-83, 9-12 October 1995.

OTHER:

Wash, C.H., Davidson, K.L., and Jordan, M.S., "Multispectral Remote Sensing of Coastal Atmospheric Boundary Layer," submitted to Eighth Conference on Satellite Meteorology and Oceanography.

DOD KEY TECHNOLOGY AREAS: Environmental Quality, Sensors

KEYWORDS: Meteorological measurement, marine atmosphere boundary layer, radar refraction

VERIFICATION OF MARINE AEROSOL MODELS FOR COASTAL REGIONS

Kenneth L. Davidson, Professor
Department of Meteorology
Sponsor: Naval Command Control and Ocean Surveillance Center, Research and Development Division

OBJECTIVE: Evaluate/formulate marine atmospheric boundary layer aerosol models on basis of analyses and interpretation of measurements of near-surface influencing factors.

SUMMARY: Aerosol models have been evaluated/formulated on basis of measured near-surface influencing factors. Interpretations were continued/merged from several overwater experiments; the Variability of Coastal Atmospheric Refraction (VOCAR) experiment and the Marine Aerosol Properties and Thermal Imaging Program (MAPTIP) experiment. Investigations have become directed toward assessment of aerosol properties using multi-wavelength satellite remote sensing. Aerosol data were collected from ship during R/V Point Sur cruise off the US West coast in May 1995 (EOMET-95) and the R/V Haakon Mosby ERS-2 calibration/validation experiment off the SW Norwegian coast in September 1995 (NORCSEX'95). Remote sensing feasibility examinations are on the detection of aerosol from multi-frequency satellite imagery. Data are from all shipboard collection. Results show that the model is reasonable unless there is an influence by offshore advected aerosol, i.e. sea surface source is violated.

CONFERENCE PRESENTATIONS:

Davidson, K.L. and Wash, C. H., "Remote Measurement of Atmospheric Refraction Conditions in the Coastal Region," AGARD-CP-557, 4.1 - 4.6, 1995.

Wash, C. H., Davidson, K. L., and Jordan, M. S., "Remote Measurement of Coastal Marine Atmospheric Boundary Layer (MABL) Features," Proceedings, IGARSS'95, Florence, Italy 10-14 July 1995.

Wash, C.H., Davidson, K.L., and Jordan, M.S. "Remote Measurement of the Coastal Marine Atmospheric Boundary Layer," Proceedings, OCEANS'94, San Diego, CA, 9-12 October, 1995, 79-83, 1995.

DOD KEY TECHNOLOGY AREAS: Environmental Quality, Sensors

KEYWORDS: Aerosol, EO propagation, marine atmosphere boundary layer

SMALL COMBATANT ELECTRO-MAGNETIC/ELECTRO-OPTICAL (EM/EO) SENSORS

Kenneth L. Davidson, Professor
Carlyle H. Wash, Professor
Department of Meteorology
Sponsor: Space and Naval Warfare Command

OBJECTIVE: Provide the Navy with the capability to obtain descriptions of EM/EO conditions from small combatants in the Littoral Zone on the basis of *in situ* measurements through the use of state-of-the-art METOC instrumentation coupled to the NITES/JMCIS architecture.

SUMMARY: Five (5) METOC systems were evaluated during three separated deployments; two were off the US west coast and one off the SW Norwegian Coast. The evaluation and deployments were designed for measurement accuracy, acquisition adaptability and field performances. A candidate system has been selected for focusing further analyses and comparisons against other components. The systems performance has been shown to depend on mounting configuration. Support was provided on gathering climatological data for purpose of conducting a Cost-Effectiveness-Analysis (COEA) for eventual deployment of LIDAR instead of Rawinsondes at USN launch locations; ashore and at-sea. Support was also provided to aerosol technological development effort during all three of the system evaluation/deployment campaigns. An evaporation duct modeling and measurement workshop held.

PUBLICATIONS:

Davidson, K. L., "Technical Design Options for Small Combatant METOC Instrumentation Systems," 26 October 1995, with IPD.

Davidson, K.L., "Evaluation of METOC Sensors On SHAREM 110," 27 October 1995, with IPD.

Davidson, K. L., "Evaluation of GPS Ship Course/Speed Calculations for Determination of True Wind Vectors," October 1995, with IPD.

Davidson, K.L. and Wash, C.H., "Small Combatant Requirements for METOC EM/EO Sensors," Proceedings, SPAWAR 175 RDT&E Review, NRL-Monterey, CA, 25 January 1995.

CONFERENCE PRESENTATION:

Davidson, K.L. and Wash, C.H., "Small Combatant Requirements for METOC EM/EO Sensors," SPAWAR 175 RDT&E Review, NRL-Monterey, CA, 25 January 1995.

THESIS DIRECTED:

Byers, D., "Synoptic and Mesoscale Influences on Refraction during SHAREM 110," Master's Thesis, December 1995.

DOD KEY TECHNOLOGY AREAS: Environmental Quality, Sensors

KEYWORDS: Meteorological measurement, marine atmosphere boundary layer, radar refraction

EVALUATION OF BUOY MOTION/ORIENTATION MEASUREMENT

Kenneth L. Davidson, Professor
Department of Meteorology
Sponsor: Naval Research Laboratory, Stennis Space Center

OBJECTIVE: Perform analysis and field evaluations on buoy motion and/or orientation measurements and to evaluate potential impact on obtaining surface wave conditions and near-surface refractive descriptions. The AN/SWQ-6 performance is the objective of the analysis and field evaluation. However, these will be performed with regard to toroid as well as AN/SWQ-6 hulls since an existing toroid based system enables considerable testing configurations.

SUMMARY: *In situ* evaluation were performed of two recent systems with regard to buoy motion and orientation measurement and interpretation for geophysical influences, i.e. two-dimensional wave field. Recent advances in solid state rotational sensing and miniaturization of electronics provide new lines of sensors that appear to be well suited for buoy applications. Further, procedures have been developed to relate these measured motions to geophysical descriptions; i.e., the wave field and to influences on wind velocity measurements. The motion systems evaluated were the: 1) Systron Donner (Inertial Division) MotionPak, a motion (pitch, roll, and heave) sensor and, 2) Precision Navigation, Inc. TCM2 Electronic Compass, an orientation (pitch, roll and direction) sensor.

DOD KEY TECHNOLOGY AREAS: Environmental Quality, Sensors

KEYWORDS: Measurements, EM/EO propagation, sea surface temperature, marine atmosphere boundary layer, evaporation duct

METEOROLOGY

WIND/METEOROLOGICAL ANALYSES (NORCSEX-1991)

Kenneth L. Davidson, Professor
Department of Meteorology
Sponsor: Naval Research Laboratory, Stennis Space Center

OBJECTIVE: To calibrate/validate algorithms for interpreting physical feature or process associated with active radar (SAR and Scatterometer) measurements. To explain wind-wave coupling processes on basis of merged *in situ* and remote measured data sets.

SUMMARY: This is a continuing effort involving *in situ* measurements under the European Remote Sensing (ERS 1/2) satellites. NORCSEX'91 and NORCSEX'95 were calibration/ validation in situ data collection efforts for ERS-1/2 and were conducted off the west coast of Norway 26-29 November 1991 and 7-30 September 1995. NPS performed continuous measurements of the atmospheric surface layer from a ship and a buoy and regular spaced measurements of the boundary layer profile and performed analyses to demonstrate and validate ERS-1 capabilities of detecting near surface mesoscale wind field variations. Accomplishments were to contribute to a development of the SAR wind algorithm and to verify a relationship between friction velocity and backscatter data.

CONFERENCE PRESENTATIONS:

Davidson, K.L. and Wash, C.H., "Remote Measurement of Atmospheric Refraction Conditions in the Coastal Region," Proceedings, 2nd Symposium of the Sensor and Propagation Panel of AGARD on Propagation Assessment in Coastal Environments, Bremerhaven, Germany, AGARD-CP-557, 4.1-4.6, 19-23 September 1995.

Davidson, K.L., Weissman, D.E., Onstott, R.G., van Halsema, E., "Scatterometer Algorithms and Meso-scale wind Regimes," Proceedings, IGARSS '95, Florence, Italy, pp. 1624-1628, 10-14 July 1995.

Davidson, K.L., Weissman, D.E., Onstott, R., and van Halsema, E., "Coastal Applications of Scatterometer Wind Algorithms," Proceedings, OCEANS '95, San Diego, CA, pp. 1251-1258, 9-12 October 1995.

DOD KEY TECHNOLOGY AREAS: Environmental Quality, Sensors

KEYWORDS: Wind stress, marine atmosphere boundary layer, remote sensing, scatterometer, radar refraction

NEAR SURFACE INFRARED REFRACTION (IR) STUDY SUPPORT

Kenneth L. Davidson Professor
Department of Meteorology
Sponsor: Naval Research Laboratory, Washington, DC

OBJECTIVE: Buoy and data collection design will be performed to support IR thermal imager program (IRAMMP). IRRAMP is designed to determine performance with target approaching from close to the horizon. Objectives of this effort will be to evaluate: 1) obtaining near surface temperatures from a moored buoy and, 2) buoy data-link technology.

SUMMARY: The design effort was to match measurement requirements for IR refraction with the capabilities of procedures and techniques used successfully with the NPS buoy. Efforts continuing through deployment in CY95 included: 1) evaluating requirements for IR refraction data collection, 2) evaluating adapting sensors and procedures used with NPS buoy to refraction studies, 3) arranging candidates for mooring design and construction, and, 4) evaluating power and ruggedness limits for planned measurements.

METEOROLOGY

DOD KEY TECHNOLOGY AREAS: Environmental Quality, Sensors

KEYWORDS: IR refraction, buoy, IRAMMP

TROPICAL CYCLONE MOTION STUDIES

Russell L. Elsberry, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: A long-term goal of this continuing project is to develop a unified view of the mesoscale, synoptic-scale, and large-scale environmental components of the tropical cyclone motion problem.

SUMMARY: A new book entitled Global Perspectives on Tropical Cyclones was published. Professor Elsberry served as editor and also authored the chapter on tropical cyclone motion. A review of advancements in dynamical tropical cyclone track predictions has appeared (Elsberry 1995).

Analysis of the Tropical Cyclone Motion (TCM-90) field experiment data indicates that the cyclones were embedded in cyclonic shear of the environmental flow averaged between 850 and 300 mb (Elsberry 1995). The surprising aspect is that cyclonic shear continued throughout the life cycle, rather than just during formation. Vertical wind shear calculated from operational analyses often exceeds the accepted threshold values during formation (Elsberry and Jeffries 1995). A new interactive analysis results in vertical shears that are below the threshold values, and thus are consistent with the observed formation and intensification.

PUBLICATIONS:

Dobos, P.H., Lind, R. J., and Elsberry, R. L., "Surface Wind Comparisons with Radar Wind Profiler Observations Near Tropical Cyclones," Weather and Forecasting, Vol. 10, pp. 564-575, 1995.

Elsberry, R.L., "Tropical Cyclone Motion," Chap. 4, Global Perspectives on Tropical Cyclones, (R. L. Elsberry, Ed.) Tech. Doc. WMO/TD 693, World Meteorological Organization, Geneva, Switzerland, 289 pp, 1995.

Elsberry, R.L., "Recent Advancements in Dynamical Tropical Cyclone Track Predictions," Meteorology Atmospheric Physics, Vol. 56, 81-99, 1995.

Elsberry, R.L. and Jeffries, R.A., "Vertical Wind Shear Influences on Tropical Cyclone Formation and Intensification during TCM-92 and TCM-93," accepted for publication in Monthly Weather Review, 1995.

CONFERENCE PRESENTATIONS:

Elsberry, R.L., "Environmental Flow Fields Near Tropical Cyclones during TCM-90," Preprints, 21st Conference Hurricanes Tropical Meteorology, American Meteorological Society, Boston, MA, pp. 9-11, 1995.

Jeffries, R.A., Carr, L.E., and Elsberry, R.L., "An Interactive Objective Analysis Technique for Tropical Regions," Preprints, 21st Conference Hurricanes Tropical Meteorology, American Meteorological Society, Boston, MA, pp. 246-248, 1995.

Elsberry, R.L. and Carr, L.E., "Effects of Large-scale Environmental Fields on Tropical Cyclone Motion," Fourth Technical Conference on SPECTRUM, Tsukuba, Japan, November 1995.

Elsberry, R.L., "Recent Activities Related to TCM-90," Fourth Technical Conference on SPECTRUM, Tsukuba, Japan, November 1995.

Elsberry, R.L., Goerss, J.R., Mauck, C., and Rennick, M.A., "Operational Typhoon Forecasting at the Fleet Numerical Meteorology and Oceanography Center," Fourth Technical Conference on SPECTRUM, Tsukuba, Japan, November 1995.

THESES DIRECTED:

Jeffries, R.A., "Evaluation of an Interactive Regional Wind Analysis Procedure for the Tropics," Master's Thesis, September 1995.

Kalafsky, M.S., "Repetitive Tropical Cyclogenesis during TCM-93," Master's Thesis, June 1995.

Kent, C.S.T., "Systematic and Integrated Approach to Tropical Cyclone Track Forecasting in the North Atlantic," Master's Thesis, December 1995.

White, S.R., "Systematic and Integrated Approach to Tropical Cyclone Track Forecasting in the Eastern and Central North Pacific," Master's Thesis, December 1995.

DOD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Tropical meteorology, tropical cyclones, tropical cyclone motion

FEASIBILITY STUDY OF A WEST COAST PICKET FENCE SPECIFICATION OF UPSTREAM BOUNDARY CONDITIONS FOR STORM

Russell L. Elsberry, Professor
Paul A. Hirschberg, Assistant Research Professor
Richard J. Lind, Meteorologist
Department of Meteorology
Sponsor: National Science Foundation

OBJECTIVE: The objective of this project was to demonstrate that a "Picket Fence" of extra rawinsonde stations along the U.S. west coast would improve the time and spatial resolution of the mass, heat, momentum, potential energy, kinetic energy and moisture carried by jet streaks and short waves entering the U.S. from the conventional data-sparse Pacific Ocean. A consequence of this improved specification of the "upstream boundary" conditions will be a more accurate forcing of the mesoscale weather systems that develop over the central U.S.

SUMMARY: To accomplish the objectives of the Picket Fence Experiment, an array of seven new rawinsonde stations interspersed among the seven operational stations was deployed along the west coast of the U.S. during the STORM-Fronts Experiment Systems Test (STORM-FEST) in February-March 1992. Additionally, rawinsondes were launched every 3 h at all sites rather than the regular 12-h intervals to improve the temporal resolution of the data during four intensive observation periods. The field portion of the experiment demonstrated the operational feasibility of obtaining extra spatial and temporal observations via the Picket Fence approach and is documented in Lind et al. (1992). The potential boundary-condition impact of the Picket Fence was investigated by comparing the fluxes of mass, heat, momentum, potential energy, kinetic energy and moisture across the west coast resolved with various spatial and temporal combinations of Picket Fence data against a standard calculated with only the 12-h regular upper-air sites. In the best case, when a wave system crossed the middle of the Picket Fence, significantly different fluxes were calculated with the full spatial and 3-h Picket Fence observations, which therefore validates the hypothesis.

METEOROLOGY

PUBLICATION:

Hirschberg, P.A., Lind, R.J., Bolduc, S. J., and Elsberry, R.L., "The Picket Fence Experiment during STORM-FEST," Bulletin of the American Meteorological Society, Vol. 76, 1741-1757, October 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Atmospheric effects, mesoscale weather predictions, lateral boundary conditions

ATMOSPHERIC FORCING DURING THE ANZONE WINTER FLUX EXPERIMENT (ANZFLUX)

Peter S. Guest, Meteorologist
Kenneth L. Davidson, Professor
Department of Meteorology
Sponsor: National Science Foundation

OBJECTIVE: The research was a closely integrated part of a multiple investigator program called the Antarctic Zone Flux Experiment (ANZFLUX) which addressed the problem of explaining the anomalously high heat fluxes which occur across the oceanic mixed layer in the Eastern Weddell Sea. Atmospheric forcing of the upper ocean was measured and analyzed using instruments from ship, ice floe and balloon platforms.

SUMMARY: This was the second year of a three year program to characterize air-sea-ice interactions in the Weddell Sea. We have found that the variations and the mean value of the total surface heat flux were primarily determined by the longwave radiation balance during the ANZFLUX project. The longwave radiation balance, in turn, was mostly controlled by the amount of clouds. Despite intense storm activity, cloud conditions, not surface wind speed nor air temperature, dominated the direct thermodynamic forcing of the atmosphere on the ocean. In addition to the work concerning the Weddell Sea some final work on previous research projects was completed.

PUBLICATIONS:

Guest, P.S., "Surface Heat Fluxes in the Eastern Weddell Sea During Winter," to appear Antarctic Journal of the United States.

McPhee, M., Ackley, S., Guest, P., Huber, B., Martinson, D., Morison, J., Muench, R., Padman, L., and Stanton, T., "The Antarctic Zone Flux Experiment," to appear Monthly Weather Review.

Guest, P.S., Davidson, K.L., Overland, J.E., and Frederickson, P.A., "Atmosphere-Ocean Interactions in the Marginal Ice Zones of the Nordic Seas," Arctic Oceanography: Marginal Ice Zones and Continental Shelves Coastal and Estuarine Studies, Vol. 49, Smith and J. Grebmeier, Eds., American Geophysical Union, pp. 51-95, 1995.

Guest, P.S., Glendening, J.W., and Davidson, K.L., "An Observational and Numerical Study of Wind Stress Variations Within Marginal Ice Zones," Journal of Geophysical Research, Vol. 100, 10,887-10,904, 1995.

Guest, P.S. and Davidson, K.L., "The Temperature and Energy Balance at the Marine Ice-Atmosphere Interface During the Polar Winter, Snow and Ice Covers: Interactions with the Atmosphere and Ecosystems," IAHS Publication No. 223, H. G. Jones, T. D. Davies, A. Ohmura and E. M. Morris, Eds., IAHS Press, Wallingford, UK, 340 pp., 1995.

CONFERENCE PRESENTATION:

Guest, P.S., "The Surface Heat and Momentum Budgets of the Eastern Weddell Sea in Winter," Poster presentation, IAPSO XXI assembly, 5-12 August 1995.

THESIS DIRECTED:

Johnson, J.C. "Turbulent Heat Flux Measurements Over the Greenland, Norwegian, and Barents Seas," Master's Thesis, 1995.

OTHER:

Rasmussen, E.A., Guest, P.S., and Davidson, K.L.,"Synoptic and Mesoscale Features Over the Ice-Covered Portion of the Fram Strait in Spring," submitted to Journal of Geophysical Research.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Weddell Sea, heat flux, wind stress, air/ice ocean interactions, marine atmospheric boundary layer

DIGITAL FILTER INITIALIZATION IN THE OCEAN

Robert L. Haney, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: This research is to test and verify a new method of initializing a primitive equation model of the coastal oceans. The initialization method, referred to as Digital Filter Initialization (DFI), was recently developed by Lynch and Huang (Monthly Weather Review 1992) for use in an intermittent data assimilation system in the atmosphere. The DFI method consists of applying a digital filter to time series of model variables generated by short term backward and forward integrations starting from an uninitialized analysis. The objective of this study is to examine the performance of the DFI method in controlled numerical experiments in the coastal oceans.

SUMMARY: The DFI dynamic initialization method is being tested and verified using data from primitive equation model simulations of linear Rossby waves, growing baroclinic waves, and nonlinear flow over steep coastal topography. Preliminary results show that the accuracy of the method is dependent on the choice of filter span (i.e., the model integration period) and the number of times the DFI procedure is repeated. Acceptable accuracy is obtainable for some values of these parameters but not all.

PUBLICATIONS:

Haney, R.L., Hale, R.A., and Collins, C., "Estimating Subpycnocline Density Fluctuations in the California Current Region from Upper Ocean Observations," Journal of Atmospheric and Oceanic Technology, Vol. 12(3), pp. 550-566, 1995.

Viudez, A., Haney, R.L., and Tintore, J., "Circulation in the Alboran Sea as Determined by Quasi-Synoptic Hydrographic Observations. Part 2. Mesoscale Ageostrophic Motion Diagnosed Through Density Dynamical Assimilation," to appear Journal of Physical Oceanography.

CONFERENCE PRESENTATIONS:

Haney, R.L., Viudez, A., and Chumbinho, R., "The Use of Digital Filter Initialization to Diagnose the Mesoscale Circulation and Vertical Motion in the Coastal Ocean," XXI General Assembly of IAPSO, Honolulu, HI, 5-12 August 1995.

Viudez, A., Haney, R. L., and Tintore, J., "Ageostrophic Motion in the Alboran Sea as Diagnosed Through Density Dynamical Assimilation," XXI General Assembly of IAPSO, Honolulu, HI, 5-12 August 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean data assimilation, coastal ocean dynamics

STRUCTURE AND DYNAMICS OF COASTAL OCEAN FILAMENTS EASTERN BOUNDARY CURRENT/ACCELERATED RESEARCH INITIATIVE (EBC/ARI)

Robert L. Haney, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: The broad objective of this research is to explore the structure and dynamics of cold filaments in eastern boundary current (EBC) regions using model-data assimilation.

SUMMARY: *In-situ* hydrographic data and remotely sensed sea surface temperature data were analyzed to describe the kinematics and dynamics of a closed cyclonic eddy observed off Point Arena, California, in May 1993. The hydrographic data were first objectively analyzed, and the resulting density field was used in a primitive equation (PE) model with a digital filter initialization (DFI) method to diagnose a dynamically balanced velocity field, including the vertical motion. The results reveal a closed cyclonic circulation about 80 km in diameter with meanders in the otherwise nearly circular flow, and maximum horizontal currents of about 40-50 cm/s at the surface. The meanders have associated patterns of radially aligned patches of sinking and rising motion, extending coherently to about 500 m depth, with maximum vertical velocities of 20-22 m/day between 100 and 150 m depth. The vertical motions obtained using the quasi-geostrophic (QG) omega equation are about 30 percent larger than the PE based values due to the neglect of ageostrophic advection in the QG system. Finally, a generalized omega equation was derived and interpreted in terms of the Lagrangian change of differential relative vorticity in a fluid parcel. The new equations is shown to be useful for interpreting non-quasigeostrophic vertical velocity as may be obtained by the DFI method.

PUBLICATIONS:

Viudez, A., Tintore, J., and Haney, R.L., "Circulation in the Alboran Sea as Determined by Quasi-Synoptic Hydrographic Observations. Part 1. Three-Dimensional Structure of the Two Anticyclonic Gyres," to appear Journal of Physical Oceanography.

Viudez, A., Tintore, J., and Haney, R.L., "About the Nature of the Generalized Omega Equation," to appear Journal of the Atmospheric Sciences.

CONFERENCE PRESENTATION:

Chumbinho, R., Haney, R.L., and Ramp, S., "Kinematics and Dynamics of a Cyclonic Eddy Off Pt. Arena, California," XII General Assembly of IAPSO, Honolulu, HI, 5-12 August 1995.

METEOROLOGY

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean data assimilation, coastal ocean dynamics

ATMOSPHERIC COMNAVMETOCCOM INDEPENDENT MODEL REVIEW PANEL (CIMREP)

Robert L. Haney, Professor
Department of Meteorology
Sponsor: Commander, Naval Meteorology and Oceanography Command (COMNAVMETOCCOM)

OBJECTIVE: The Principal Investigator chairs the Atmospheric COMNAVMETOCCOM Independent Model Review Panel (CIMREP). This panel is tasked to perform independent validation reviews of models submitted to the Oceanographic and Atmospheric Master Library (OAML), and to provide recommendations concerning incorporation of those models into OAML, including future model improvements.

SUMMARY: Two Atmospheric CIMREPs were convened in the past two years. The major one concerned the Radio Physical Optics (RPO) model developed by NRaD which was accepted into OAML with rather minor revisions. Another CIMREP is presently active in evaluating two models; one for computing pressure altitude and density altitude (PADA) and one for a temperature utility (TEMP UTIL) computation. The final CIMREP report on RPO was submitted on 1 June 1995 and the first draft reports on PADA and TEMP UTIL were completed in September 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Electromagnetic propagation

TROPICAL CYCLONE MOTION STUDIES

Patrick A. Harr, Research Assistant Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: One long-term goal of this continuing project is to understand the control of the large-scale circulation and its variability on tropical cyclone motion characteristics. The objective is to extend track forecasting into the medium range beyond 72 h. The second goal is to understand the effects of mesoscale convective systems (MCSs) on the short-term motion of tropical cyclones and on the formation of tropical cyclones. In this case, the objective is to improve the accuracy of short-range forecasts (less than 24 h) of tropical cyclone characteristics.

SUMMARY: Harr and Elsberry (1995) used a combination of multivariate statistical techniques to characterize large-scale circulation patterns in a framework that identifies favorable and unfavorable locations of tropical cyclone occurrence and track types. The evolutions of the atmospheric variability within this framework involve scales of motion that include tropical cyclones, synoptic-scale waves, monsoon circulations and global-scale circulations. In addition, the unique application of a fuzzy cluster analysis to the definition of this atmospheric variability framework is significant since the relative contribution of each pattern to the total circulation is identifiable and can be used to infer sequences of atmospheric circulations. This is expected to provide a sound basis for extended-range predictions of tropical cyclone characteristics.

Kalafsky *et al.* (1995) and Harr *et al.* (1995) document one case during the Tropical Cyclone Motion (TCM-93) experiment where a persistent large-scale circulation pattern, which contained a large monsoon gyre that was located

to the west of a strong subtropical ridge over the tropical western North Pacific, was responsible for repeated tropical cyclone genesis and north-oriented track types over a 10-day period. Furthermore, formation of a small northward-moving tropical cyclone was related to a midlevel circulation that was observed during two aircraft missions into a broad region of deep convection that was continually forced by the large-scale circulation. Data gathered during the two TCM-93 aircraft missions provided unique documentation of the formation and movement of a midget tropical cyclone.

Based on data gathered during two TCM-93 aircraft missions, Harr *et al.* (1995) define the structure of a large monsoon depression. However, the sporadic convection was highlighted by episodes of MCS development and decay without significant interaction with the monsoon depression circulation, which evolved slowly. When convection began near the center and the outer convection became organized into a long band, the monsoon depression circulation became more focused around the central convection. Following the transformation to a typhoon, a large MCS formed along a convective band that was located north of the tropical cyclone center. Harr and Elsberry (1995) used data from the final two TCM-93 aircraft missions to define the three dimensional structure of the MCS that was embedded in the typhoon circulation. During the observation period, the MCS was rapidly advected from north to west of the typhoon center and the typhoon was observed to slow dramatically and begin a turn to the north. However, detailed observations gathered during the aircraft missions indicate that the MCS structure was severely sheared by the strong primary circulation around the tropical cyclone. it was concluded that the severely weakened MCS structure could not have been responsible for the dramatic change in the motion of the tropical cyclone, which was related to variations in the large-scale steering flow that occurred at the same time.

PUBLICATIONS:

Harr, P.A. and Elsberry, R.L., "Large-scale Circulation Variability Over the Tropical Western North Pacific. Part I: Spatial Patterns and Tropical Cyclone Characteristics," Monthly Weather Review, Vol. 123, pp. 1225-1246, 1995.

Harr, P.A. and Elsberry, R.L., "Large-scale Circulation Variability Over the Tropical Western North Pacific. Part II: Persistence and Transition Characteristics," Monthly Weather Review, Vol. 123, pp. 1247-1268, 1995.

Harr, P.A. and Elsberry, R.L., "Structure of a Mesoscale Convective System Embedded in Tropical Cyclone Robyn during TCM-93," to appear Monthly Weather Review.

Harr, P.A., Kalafsky, M.S., and Elsberry, R.L., "Environmental Conditions Prior to Formation of a Midget Tropical Cyclone During TCM-93," to appear Monthly Weather Review.

CONFERENCE PRESENTATIONS:

Elsberry, R.L. and Harr, P.A., "Results from the TCM-93 Field Experiment," 1995 Tropical Cyclone Conference, Tokyo, Japan, February 1995.

Harr, P.A. and Elsberry, R.L., "Structure of a Mesoscale Convective System Embedded in Tropical Cyclone Robyn during TCM-93," 21st Conference Hurricanes Tropical Meteorology, American Meteorological Society, Boston, MA, 1995.

Harr, P.A. and Elsberry, R.L., "Evolution of a Monsoon Depression into a Tropical Storm over the Tropical Western North Pacific," Pacific Science Congress, Beijing, China, June 1995.

Kalafsky, M.S., Harr, P.A., and Elsberry, R.L., "Repetitive Tropical Cyclogenesis during TCM-93," 21st Conference Hurricanes Tropical Meteorology, American Meteorological Society, Boston, MA 1995.

THESIS DIRECTED:

Kalafsky, M.S., "Repetitive Tropical Cyclogenesis during TCM-93," Master's Thesis, June 1995.

OTHER:

Harr, P.A., Elsberry, R.L., and Chan, J.C.-L., "Transformation of a Large Monsoon Depression to a Tropical Storm during TCM-93," submitted to Monthly Weather Review.

Chang, C.-P., Chen, J.-M., Harr, P. A., and Carr, L. E., "Northwestward-propagating Wave Patterns over the Tropical Western North Pacific during Summer," submitted to Monthly Weather Review.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Tropical cyclones, tropical meteorology, mesoscale meteorology

EXAMINATION OF PRESSURE TENDENCY MECHANISMS IN IDEALIZED SIMULATIONS OF EXTRATROPICAL CYCLOGENESIS

Paul A. Hirschberg, Assistant Research Professor
Department of Meteorology
Sponsor: Naval Postgraduate School

OBJECTIVE: The objective of this project was to examine pressure tendency mechanisms in idealized simulations of extratropical cyclogenesis with a new height coordinate-based numerical model.

SUMMARY: A numerical simulation of an idealized extratropical cyclogenesis from Navy's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) was used to examine the pressure tendency mechanisms following the surface low center. The novelty of this study, performed in collaboration with Dr. James D. Doyle of the Naval Research Laboratory- Monterey, was that density and pressure tendency components could be extracted directly from COAMPS because it is a height coordinate-based model. It was found that horizontal density advection, which maximizes near a developing tropopause undulation was the primary mechanism by which the density and hydrostatic pressure was reduced in the column following the developing low center. In general, these results are consistent with historical as well as more recent studies that suggest the importance of tropopause-level temperature advection in the promotion of observed height tendency patterns accompanying the superposition of tropopause and ground-based potential vorticity anomalies during cyclogenesis.

PUBLICATION:

Hirschberg, P.A. and Doyle, J.D., "An Examination of Pressure Tendency Mechanisms in an Idealized Simulation of Extratropical Cyclogenesis," Tellus, 47A, pp. 747-758, December 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Atmospheric dynamics, extratropical cyclogenesis, numerical modeling

METEOROLOGY

GLOBAL AND TROPICAL SYSTEMS

Tom Murphree, Research Assistant Professor
Chih-Pei Chang, Professor
Jeng-Ming Chen, Research Assistant Professor
Department of Meteorology
Sponsor: Naval Research Laboratory

OBJECTIVE: This continuing project is designed to: (1) identify the dominant mechanisms of short term climate change in the global atmosphere-ocean system; (2) evaluate the atmospheric and oceanic products produced by operational analyses and forecasts; and, (3) contribute to the improvement of atmospheric and oceanic extended range forecasts.

SUMMARY: In collaboration with colleagues at NRL-Monterey and NPS students, four main research topics were pursued during 1995.

(1) Modeling Studies of the Remote Impacts of Tropical Cyclones: Experiments continued with the Navy's model (NOGAPS), and a new set of experiments were started with a global nonlinear shallow water model. These experiments were used as a low cost complement to the NOGAPS experiments. The main results confirmed the importance of the basic state in the initiation, wave guiding, and amplification of the response. The results also showed that: (1) the responses with January and July basic states were very different from each other in ways that were consistent with key differences in the dynamical of the two basic states; (2) the responses to disturbances in the Indian Ocean region were comparable to those from west Pacific disturbances, but the responses to Atlantic disturbances were much different; and (3) the NOGAPS responses over the North Pacific - North American (NPNA) region to typhoon Seth were very similar to the monthly anomalies that were observed during Seth's occurrence in October 1994.

(2) Comparisons of Analyzed and Modeled Tropical - Extratropical Interactions: Comparisons continued of analyzed and modeled atmospheric variability, focusing on intraseasonal time scales and interactions of the tropics and extratropics. Results showed that errors in the NOGAPS circulation means and variances resulted in significant errors in the model's extended range simulations. In particular, tropical errors led to clear tropical - extratropical teleconnection errors. These errors were especially pronounced in the NPNA region, where tropical - extratropical interactions appeared to be relatively strong. These errors were less pronounced in the North Atlantic region, where tropical - extratropical interactions appeared to be relatively weak. Errors in extratropical circulation (e.g., in the strength and location of jets) also led to teleconnection errors.

(3) Observational Studies of Equatorial Ocean-Atmosphere Dynamics: Analyses was extended of equatorial ocean and atmosphere data from the TOGA buoy array to investigate Kelvin waves, tropical cyclones, and tropical instability waves (TIW) during the entire 1991-1993 El Niño period. The Kelvin waves and TIWs during this period were responsible for much of the intraseasonal variability in the upper equatorial Pacific Ocean. Throughout 1991-1993, the Kelvin waves had a relatively large latitudinal extent, with clear signals as much as 5° off the equator. The Kelvin waves had a very weak SST signal, while the TIWs had a very strong SST signal that was out of phase with the subsurface temperature signal. In contrast to the Kelvin waves, the TIWs showed no clear relationships with local or remote surface winds. There was strong TIW activity in the central and eastern equatorial Pacific during June - September 1992 which coincided with the resurgence of the 1991-1992 El Niño. Since modeled TIWs tend to produce equatorward heat convergence, this suggests that the TIWs during this period may have contributed to the extension of the 1991-1992 El Niño into 1993.

(4) Observational Studies of Tropical Impacts on the North Pacific - North American Region: A study was conducted of observed atmosphere and ocean anomalies in the northeast Pacific and their association with tropical forcing during the past 15 years. It was found that the extratropical atmosphere and ocean anomalies in this region during El Niño (EN) events tend to be distinctly opposite to those during La Niña (LN) events. The major atmospheric anomalies over the northeast Pacific were consistent with an atmospheric Rossby wave teleconnection process. In addition, the atmospheric forcing associated with these atmospheric anomalies was consistent with the observed ocean anomalies. This suggests

that the ocean anomalies were, in part, a result of an atmospheric Rossby wave teleconnection process. For several EN and LN events, the atmospheric anomalies persisted into the northern spring and caused large impacts on coastal upwelling. The effects of several EN and LN events on the extratropical atmosphere and ocean persisted for up to 12 months after the EN and LN anomalies in the tropics were gone. EN and LN events were not the only tropical factors that appear to have significantly influenced the northeast Pacific. Preliminary studies of several northern spring, summer, and fall seasons suggest that intraseasonal tropical disturbances in the Indian Ocean and western Pacific (e.g., unusually strong tropical cyclone activity in the Bay of Bengal during the summers of 1991 and 1995) may have produced significant atmospheric and ocean anomalies across the northeast Pacific.

PUBLICATIONS:

Murphree, T. and Reynolds, C. "El Niño and La Niña Effects on the Northeast Pacific: the 1991-1993 and 1988-1989 Events," California Cooperative Oceanic Fisheries Investigations Reports, Vol. 36, pp. 45-56, 1995.

Reynolds, C., Gelaro, R., and Murphree, T., "Observed and Simulated Northern Hemisphere Intraseasonal Circulation Anomalies and the Influence of Model Bias," to appear Monthly Weather Review, Vol. 124.

CONFERENCE PRESENTATIONS:

Murphree, T., Gelaro, R., Reynolds, C., and Goerss, J., "Teleconnections Induced by Transient Tropical Disturbances," Fall Meeting of the American Geophysical Union, San Francisco, CA, December 1995.

Reynolds, C., R. Gelaro, and T. Murphree, "Intraseasonal Variability in a 10-Year Integration of the Navy Operational Global Atmospheric Prediction System," The First International Atmospheric Model Intercomparison Project Scientific Conference, Monterey, CA, May 1995.

Reynolds, C., R. Gelaro, and T. Murphree, "The Propagation of Extratropical Waves Into the Tropics on the 6- to 30-Day Timescale," Fall Meeting of the American Geophysical Union, San Francisco, CA, December 1995.

THESES DIRECTED:

Jakus, C., "The Remote Impacts of a Western Pacific Tropical Cyclone," Master's Thesis, September 1995.

Malsick, M., "The Dynamics of Teleconnections Induced by Short Term Tropical Forcing," Master's Thesis, September 1995.

OTHER:

Murphree, T., and Gelaro, R., "Interactions Between Equatorial Ocean Kelvin Waves and Tropical Cyclones During the 1991-1993 El Niño," to be submitted to Journal of Geophysical Research..

Murphree, T., and Gelaro, R., "The Global Scale Impacts of Individual Tropical Cyclones. Part I: Idealized Model Experiments," to be submitted to Journal of Climate.

Murphree, T., Gelaro, R., and Goerss, J., "The Global Scale Impacts of Individual Tropical Cyclones. Part II: NWP Model Experiments," to be submitted to Journal of Climate.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Atmosphere-ocean dynamics, climate dynamics, El Niño, La Niña, modeling, teleconnections, tropical cyclones, analysis and forecast systems, extended range forecasts

REAL-TIME ENVIRONMENTAL INFORMATION NETWORK AND ANALYSIS SYSTEM (REINAS)

Wendell A. Nuss, Associate Professor
Paul A. Hirschberg, Research Assistant Professor
Department of Meteorology
Sponsors: Office of Naval Research and
University of California, Santa Cruz

OBJECTIVE: The objective of this research is to develop a mesoscale observing network and real-time data assimilation system for the Monterey Bay region and assist University of California, Santa Cruz (UCSC) develop computer data base and visualization tools.

SUMMARY: This is an ongoing project and during 1995, the Naval Postgraduate School contribution to this joint research effort has focused on the development of the data assimilation system and to test the REINAS data base system from a user perspective. The Navy Operational Regional Atmospheric Prediction System (NORAPS) nested model has been used to develop a data assimilation system using multiquadric interpolation (MQ). A test case has been used for development purposes and results from this test case show the MQ approach to be viable for model initialization and was superior to the operational optimum interpolation (OI) approach used operationally by most operational models. Further development and testing is underway. The REINAS mesonet observations have been fed into the REINAS database system for some time, however, the system had not been extensively tested by scientific users. Using tools developed jointly with UCSC, the REINAS was tested extensively in 1995 and has reached a point of being fairly reliable for scientific use. New data feeds were added to the REINAS data stream by utilizing the NPS UNIDATA data feed and software developed by NPS working with UCSC.

PUBLICATION:

Mantey, P.E., Long, D.D.E., Garcia-Luna, J.J., Pang, A.T., Kolsky, H.G., Gritton, B.R., and Nuss, W.A., "REINAS: Real-time Environmental Information Network and Analysis System: Phase IV - Experimentation," University of California, Santa Cruz Technical Report, 1995.

CONFERENCE PRESENTATIONS:

Hirschberg, P.A., Nuss, W.A., and Sirayanone, S., "A ORAPS-based Analysis and Prediction System for the Monterey Bay area," NRL Mesoscale Modeling Workshop, Monterey, CA, September 1995.

Hirschberg, P.A., "The Office of Naval Research sponsored: Real-time Environmental Information Network and Analysis System (REINAS)," A prototype for on-scene shipboard analysis and forecasting, Office of Naval Research, June 1995.

OTHER:

A report describing the meteorology of the region was written for a Monterey Bay National Marine Sanctuary site characterization study being prepared by Moss Landing Marine Labs. Two papers describing the multiquadric data assimilation results are under preparation with Paul Hirschberg.

DOD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Coastal meteorology, coastal modeling, meteorological visualization

METEOROLOGY

MESOSCALE COASTALLY-TRAPPED RESPONSE TO SYNOPTIC-SCALE VARIABILITY

Wendell A. Nuss, Associate Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: The primary long term goal of this ongoing project is to understand the role that synoptic-scale circulations play in the generation, propagation and decay of coastally-trapped disturbances. Additional goals are to understand the interaction of large-scale flows with coastal topography and the nature of the mesoscale response on the lee and windward sides of the topography, as well as to improve our forecasting of the mesoscale structure based upon the large-scale circulation.

SUMMARY: During 1995, the analysis of the June 10, 1994, coastally-trapped disturbance was completed using the multiquadric analysis scheme. These analyses were used to describe the synoptic and mesoscale behaviour of this case that was observed during the pilot field program in 1994. A crucial finding of the study was that low-level advection of warm air off the central California coast was crucial for establishing the south to north coastal pressure gradient that initiates these disturbances. The results from this study were used to refine hypotheses for the upcoming field experiment in 1996. These hypotheses as well as the background scientific issues were collected in the Coastal Meteorology Science Plan written by the principal investigator as the Chief Scientist. Two workshops were planned and held during 1995 for the Coastal Meteorology program scientists to continue the planning process for the field program. To gain insight into the forecasting of the coastally-trapped disturbances, seven cases from the summer of 1995 were examined by comparing model forecasts to analyses and observations. The results of this study indicate that model guidance is useful to forecast stratus surges if care is taken in analyzing the surface and 850 mb pressure, temperature and wind fields.

CONFERENCE PRESENTATION:

Nuss, W.A., "Lee Troughing and the Evolution of a Coastally-trapped Disturbance," Seventh Conference on Mountain Meteorology, Breckenridge, CO, 17-21 July 1995.

THESIS DIRECTED:

Oosterling, P. S. "Coastally-trapped Disturbances along the U.S. West Coast: Synoptic and Mesoscale Analysis of 9-12 June 1994," Master's Thesis, September 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Coastally meteorology, coastal forecasting

MESOSCALE OBJECTIVE ANALYSIS USING MULTIQUADRIC INTERPOLATION

Wendell A. Nuss, Associate Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this research is to develop and improve a mesoscale objective analysis program based upon the multiquadric interpolation method for use with mesoscale data over the Monterey Bay region.

SUMMARY: The multiquadric interpolation scheme has been adapted for use with meteorological data over the last few years. This research has focused on how to improve the basic mathematical technique to allow for observational error and the use of numerical model first guess fields. During 1995, a method for blending numerical model data with observations was devised and tested. The method was designed to account for both model forecast error as well as

observational error. To make maximum use of the model first guess information a method was devised to extract the most mathematically relevant points out of the model to minimize the number of first guess points needed for the blend. This technique increases the computational efficiency and allows for the best use of both observations and model information. The method was also extended to three dimensions and testing is continuing on this software.

PUBLICATIONS:

Nuss, W.A., 1995: Reply to Comments on "Use of Multiquadric Interpolation for Meteorological Objective Analysis," Monthly Weather Review, Vol. 123, pp. 2257-2259, 1995.

Sirayanone S. and Hardy, R.L., "The Multiquadric-biharmonic Method as Used for Mineral Resources, Meteorological, and Other Applications," Journal of Applied Sciences and Computations, Vol. 1, pp. 437-475, 1995.

CONFERENCE PRESENTATIONS:

Sirayanone, S., "3-D stereoscopy by the Multiquadric-biharmonic," 5th International Conference on Advanced Science and Technology Exchange with Thailand, Bangkok, Thailand, 20-22 July 1995.

Sirayanone, S., "The Multiquadric-biharmonic Approximation Method Applied to the Information Technology," 5th Annual Workshop on Advanced Science and Technology Exchange, Crystal City, VA, 21-23 April 1995.

Sirayanone, S., "Optimizing the Number and Location of Observing Stations of Geophysical Data in Multiquadric-biharmonic Analysis," International Union of Geodesy and Geophysics XXI General Assembly, Boulder, CO, 2-14 July 1995.

Sirayanone, S., "The Multiquadric-biharmonic Method in the Spherical Coordinate System," American Geophysical Union 1995 Spring Meeting, Baltimore MD, 29 May - 2 June 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Coastal meteorology, data assimilation, coastal analysis

CASE STUDIES OF THE ABILITY OF THE NAVY'S MESOSCALE DATA ASSIMILATION SYSTEM TO DEPICT MESOSCALE PHENOMENA

Patricia M. Pauley, Research Associate Professor
Department of Meteorology
Sponsor: Naval Research Laboratory - Monterey

OBJECTIVE: The goal of this research is to examine the performance of the Navy's mesoscale data assimilation system for cases with strong mesoscale forcing such as accompanies jet streaks and upper fronts. Such phenomena stretch the limits of the capability of the data assimilation system but are important weather producers and therefore should be both analyzed and predicted.

SUMMARY: The work performed during calendar year 1995 in conjunction with this project fell into two catagories: preparing publications and writing diagnostic computer programs. The primary publication associated with this research described work that was begun prior to this project. An observational study of the meteorological conditions associated with the November 1991 San Joaquin Valley dust storm, an event which led to a multiple vehicle collision involving 164 vehicles on Interstate-5, had been previously undertaken but had not been written up for refereed publication. This work has now been accepted for the April 1996 issue of the *Bulletin of the American Meteorological Society*. The

remainder of the research effort was spent in developing and refining a computer program to evaluate and graphically portray a number of diagnostic quantities, including a vector form of the frontogenesis function, a kinetic energy budget, and a technique for isolating the topographic component of the vertical motion. This program is currently being applied to a series of five case studies having strong upper-level jet/front systems over California, including the previously mentioned November 1991 case.

PUBLICATION:

Pauley, P.M., Baker, N.L., and Barker, E.H., "An Observational Study of the "Interstate-5" Dust Storm Case," to appear Bulletin of the American Meteorological Society.

CONFERENCE PRESENTATION:

Pauley, P.M., Baker, N.L., and Barker, E.H., "An Observational Study of the "Interstate-5" Dust Storm Case," Ninth Extratropical Cyclone Workshop, Asilomar Conference Center, Pacific Grove, CA, 3-7 December 1995.

DOD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Data assimilation, jet streak, upper front, dust storm

A COMPARISON OF CYCLONE FORECASTS IN NATIONAL METEOROLOGICAL CENTER'S ETA AND NASTY GRID MODEL (NGM) MODELS

Patricia M. Pauley, Research Associate Professor
Department of Meteorology
Sponsor: Unfunded

OBJECTIVE: The goal of this research is to examine the upper-level forcing associated with previously cataloged extratropical cyclones in both analyses and forecasts from one of the National Meteorological Center's models for a five month period.

SUMMARY: This research built on the work performed in AY94, in which a combination of manual and numerical techniques were used to locate extratropical cyclones as minima in the sea-level pressure field, to match Eta-model predicted and analyzed cyclones verifying at the same time, and to track individual cyclones through their life cycle. The present work computed 500 mb vorticity advection and 300 mb divergence averaged over an area representing the core of the cyclone for each of the storms cataloged earlier. The 300 mb divergence was further partitioned into components associated with the along-contour and cross-contour components of the divergent ageostrophic wind, in order to assess the relative contributions of curvature and jet streaks. Statistics and graphics portraying the results were presented in a master's thesis in December 1995.

CONFERENCE PRESENTATION:

Sauer, E.L. and Pauley, P.M., " 300 mb Divergence and its Effects on Surface Cyclogenesis," Ninth Extratropical Cyclone Workshop, Asilomar Conference Center, Pacific Grove, CA, 3-7 December 1995.

THESIS DIRECTED:

Sauer, E.L., "300 mb Divergence and its Effects on Surface Cyclogenesis," Master's Thesis, December 1995.

DOD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Extratropical cyclone, jet streak, divergence, numerical modeling

A STUDY IN IMPROVING THE TROPICAL CYCLONE PREDICTION

Melinda S. Peng, Research Associate Professor
Department of Meteorology
Sponsor: Naval Research Laboratory

OBJECTIVE: To study the effect of implementing a wavenumber- one asymmetry, induced by the planetary vorticity gradient, on tropical cyclone prediction and the feasibility of assimilating rainrates constructed from infrared cloud top brightness temperature.

SUMMARY: A barotropic model was used to generate the wavenumber-one asymmetry of a vortex induced by planetary vorticity gradient. The wavenumber-one asymmetry was retrieved by Fourier analysis and then rotated and its magnitude adjusted so that the flow across the center matched the cyclone's movement at initial time. Five cases of Typhoon Flo were tested using NRL limited-area model and results are satisfactory. Rainrates constructed analytically from the infrared brightness temperature were assimilated into the same model to enhance the cyclone's intensity. The results demonstrated the feasibility of assimilating satellite-retrieved rainrates in operational prediction of tropical cyclones.

PUBLICATION:

Peng, M. S. and Chang, S.W., "Impacts of SSM/I Retrieved Rainfall Rates on Numerical Prediction of a Tropical Cyclone," to appear Monthly Weather Review.

CONFERENCE PRESENTATION:

Chang, S.W. and Peng, M.S., "Impacts of SSM/I Retrieved Rainfall Rates on Numerical Prediction of Tropical Cyclones," 21th Conference on Hurricanes and Tropical Meteorology, Miami, FL, 24-28 April 1995.

OTHER:

Peng, M.S. and Chang, S.W., "Forecast of Typhoon Flo (1990) with Assimilation of Rainfall Rates Constructed Using IR Brightness Temperature," in final preparation.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Tropical cyclone, asymmetry, assimilation

BOUNDARY LAYER AND CLOUD EVOLUTION OBSERVED DURING ASTEX

Qing Wang, Assistant Professor
Department of Meteorology
Sponsor: Naval Postgraduate School

OBJECTIVE: The objective of this project is to understand the boundary layer turbulence structure that affects the evolution of marine stratocumulus clouds from observations along the tradewind trajectory.

SUMMARY: Aircraft measurements on boundary layer turbulence structure were made in a two-day period during the Atlantic Stratocumulus Transition Experiment (ASTEX). During the measurement time period, the aircraft followed the same air column traced by balloons in the boundary layer, a measurement strategy called Lagrangian approach. The Lagrangian Intensive Observation Period (IOP) during ASTEX was the first time that boundary layer turbulence was successfully measured in a Lagrangian coordinate. This research analyzed this dataset to study the evolution of boundary layer turbulence structure and its interaction with boundary layer clouds. Using the measurements from three flights, budget analyses for boundary layer mean and turbulence quantities can be obtained. The budgets of mean potential temperature and total water in the surface-based layer suggested that drizzle evaporative cooling and condensational heating related to cumulus formation below the main stratocumulus deck play important roles in determining the temperature profile in the lower layer. The analyses on the boundary layer growth yielded an estimate for cloud-top entrainment velocity of about 1.6 cms^{-1}. It was also found that the transition from solid stratocumulus to scattered cumulus clouds may occur as a result of drizzle and solar radiation while the sea surface temperature remains nearly the same. This result points to the importance of proper simulation of drizzle and solar radiation in modeling the transition from stratiform to cumulus clouds.

PUBLICATION:

Wang, Q., "Boundary Layer Turbulence Structure Observed during the Lagrangian Measurements in ASTEX," Workshop Proceedings on Cloud Modeling and Measurement, NOAA/ETL, Boulder, CO, 23-25 October 1995.

CONFERENCE PRESENTATION:

Wang, Q., "Observations of Boundary Layer Turbulence and Cloud Structure," Cloud Modeling and Measurement Workshop, NOAA/ETL, Boulder, CO, 23-25 October 1995.

OTHER:

Zhang, C., Randall, D., Moeng, C.-H., Branson, M., Moyer, K., and Wang, Q., "A Surface Flux Parameterization Based on Vertically Averaged Turbulence Kinetic Energy," submitted to Monthly Weather Review.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Boundary layer meteorology, turbulence structure, stratocumulus clouds

ENTRAINMENT MEASUREMENTS AND BOUNDARY LAYER TURBULENCE STRUCTURE IN REMOTE MARINE ATMOSPHERE

Qing Wang, Assistant Professor
Department of Meteorology
Sponsor: Naval Postgraduate School

OBJECTIVE: The objective of this project is to measure the entrainment at the top of the atmospheric boundary layer and the boundary layer turbulence structure. The goal is to examine the effects of boundary layer dynamics in determining the chemical and physical properties of atmospheric aerosol.

SUMMARY: A new aircraft flight pattern was tested during the Aerosol Characterization Experiment (ACE-I) for improved measurement of entrainment velocity at the boundary layer top. This method provides two independent estimates of entrainment velocity from one measurement. On-site analyses of the measurements were made to estimate entrainment velocity using the flux method. Boundary layer mean and turbulence flux profiles were also obtained to determine the property of the turbulence field that generates entrainment mixing. Further study is underway to estimate the entrainment velocity using the divergence method and examine the results with more data.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Boundary layer measurements, entrainment, stratocumulus clouds

UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH (UCAR) VISITING SCIENTIST SUPPORT

Carlyle H. Wash, Professor
Department of Meteorology
Sponsor: National Oceanic and Atmospheric Administration

OBJECTIVE: Objectives are: (1) to serve as lead instructor for the COMET Mesoscale class during Fall 1995 and, (2) to develop distance learning modules for forecasters in the area of marine meteorology.

SUMMARY: COMET Mesoscale class was conducted with particular focus on coastal processes. A third marine meteorology module was prepared on forecasting superstructure icing and sea fog during 1995.

PUBLICATION:

Lyons, S., Wash, C.H., and Rinard, S., "Marine Meteorology, Volume III, Forecasting Fog and Superstructure Icing," COMET Forecaster's Multimedia Library, Cooperative Program for Operational Meteorology, Education and Training, University Corporation for Atmospheric Research, December 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Marine meteorology, sea fog, control processes

VALIDATION OF SHAREM 110 DATA FOR ENEWS DEMONSTRATION

Carlyle H. Wash, Professor
Department of Meteorology
Sponsor: Naval Research Laboratory

OBJECTIVE: Prepare a validated in situ meteorological data set, obtained from ships and predicted fields during SHAREM 110, for in interpreting factors affecting performance of RPO and for use with ENEWS demonstration.

SUMMARY: SHAREM 110 data corresponding to approximately four (4) events were validated. Initially it was assumed that half of these will be from the Arabian Sea and the other from the Gulf of Oman. Selection of the cases were made on the basis of the status of both synoptic/mesoscale events and availability of atmospheric and radar data. The data included the ship and aircraft tracks with validated detection ranges for three different radar sensors from an AEGIS ship and surface METOC observations from that ship.

Raw SHAREM atmospheric and ocean surface data that can be used to describe refractive properties were available to NRL and NPS. A detailed analysis of the multi-ship and aircraft data sets was necessary to obtain valid surface layer and radar detection data sets. The evaporation duct strength was a primary description, as well as elevated trapping areas, but the in situ surface observations were questionable. Analysis/interpretation addressed the possibility of calibrating/validating three dimensional analysis from NRL.

THESIS DIRECTED:

Byers, D., "Synoptic and Mesoscale Influences on Refraction during SHAREM 110," Master's Thesis, December 1995.

DOD KEY TECHNOLOGY AREAS: Environmental Quality, Sensors

KEYWORDS: SHAREM 110, Marine Atmosphere Boundary Layer, Radar Refraction, RPO

AN EVALUATION OF SATELLITE-BASED OBSERVATIONS OF TROPOPAUSE-LEVEL THERMAL ANOMALIES IN IMPROVING THE NOWCASTING AND FORECASTING OF EXTRATROPICAL CYCLONES

Carlyle H. Wash, Professor
Paul A. Hirschberg, Assistant Research Professor
Department of Meteorology
Sponsor: National Weather Service

OBJECTIVE: The objective of this project is to determine the utility of Microwave Sounding Unit (MSU) brightness-temperature analyses in improving the nowcasting and forecasting of extratropical cyclone events especially over conventional data-sparse regions.

SUMMARY: A statistical analysis was performed on a six-month global data set consisting of satellite-derived channel 3 Microwave Sounding Unit (MSU) brightness-temperature from the Marshall Space Flight Center and various conventionally-derived fields obtained from the National Meteorological Center Global Data Assimilation System (GDAS) to quantify the potential usefulness of MSU analyses in the nowcasting and forecasting of baroclinic waves especially over conventional data-sparse regions. High positive spatial and temporal correlations were obtained between the MSU and the 400-100-mb thickness over all wavelengths in the data. Most significantly, relatively high negative MSU-500-mb correlations for the short wave-length portion of the data suggest that the MSU can be used to track mid-level synoptic-scale baroclinic waves. An MSU collection and analysis procedure was also developed to generate MSU analyses from locally obtained polar-orbiter data.

PUBLICATION:

Hirschberg, P.A., Parke, M.C., Wash, C.H., Thaler, E., and Spencer, R.W., "The Utilization of Satellite-based Observations of Tropopause-level Thermal Anomalies in the Nowcasting and Forecasting of Extratropical Cyclones," Proceedings AMS Fourteenth Conference on Weather Analysis and Forecasting, Dallas, TX, January, 1995, pp. 317-322.

CONFERENCE PRESENTATIONS:

Hirschberg, P.A., Parke, M.C., Wash, C.H., Thaler, E., and Spencer, R.W., "The Utilization of Satellite-based Observations of Tropopause-level Thermal Anomalies in the Nowcasting and Forecasting of Extratropical Cyclones," The AMS Fourteenth Conference on Weather Analysis and Forecasting, Dallas, TX, January 1995.

Wash, C.H., Parke, M.C., and Hirschberg, P.A., "Comparison of Satellite-derived MSU Brightness Temperatures and Conventionally-derived Fields," 1995 Pacific Northwest Weather Workshop, Seattle, WA, February 1995.

THESIS DIRECTED:

Mickelinc, M.C., "Synoptic Applications of NOAA MSU Data," Master's Thesis, December 1995.

METEOROLOGY

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Satellite measurements, weather forecasting/analysis

FRONTAL MODELING

Roger T. Williams, Professor
Melinda S. Peng, Research Associate Professor
Department of Meteorology
Sponsor: National Science Foundation

OBJECTIVE: The goal of this research is to improve the modeling of atmospheric fronts. This is a continuing project.

SUMMARY: Frontogenesis over the ocean with the three-dimensional NRL regional model was studied. The model was initialized with a zonal baroclinic current plus a small perturbation. The sea surface temperature which was in balance with the atmosphere initially, was independent of time. The experiments were carried out with K-theory and second order closure boundary layer parameterizations. The dynamics of the cold front which was moving over warmer water was investigated in detail. It was found that the strong vertical mixing of momentum in the cold air caused the front to be more vertical and more intense at upper levels. The influence of topography on fronts with a three-dimensional model with no heating or friction was also studied. Cold and warm fronts formed when a cyclone grew in an unstable baroclinic current. The mountains were circular or ellipsoidal and various scales and orientations were considered. The frontal solutions, which were first developed in a region with no mountains, were fed into the mountain region with special western boundary conditions. As the cold fronts moved up the mountain slope they weakened and strong frontogenesis occurred as the front moved down the lee slope. The strongest frontogenesis was south of the east-west mountain which resembled the Alps.

PUBLICATION:

Li, S.-W., Peng, M.S., and Williams, R.T., "A Three-dimensional Study of the Influences of Mountains on a Front," accepted Journal of the Atmospheric Sciences.

OTHER:

The paper entitled "Numerical Simulations of Maritime Frontogenesis," by W.T. Thompson and R. T. Williams is in final revision for the Journal of the Atmospheric Sciences.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Fronts, boundary layer, topography

MECHANISMS OF TROPICAL CYCLONE STRUCTURE CHANGE

Roger T. Williams, Professor
Melinda S. Peng, Research Associate Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: To determine the mechanisms which cause changes in tropical cyclone structure. This is a continuing project.

SUMMARY: The effect of the planetary vorticity gradient and the inclusion of a uniform mean flow on the intensification of tropical cyclones was studied using a primitive equation model. The most intense vortex developed on a constant *f* plane with zero mean flow. The structure of this storm was symmetric with respect to the vortex center. The presence of the beta effect or a large mean flow induced an asymmetric flow across the center of the vortex which inhibited the cyclone's intensification. Fourier analyses of the asymmetry showed that a deepening cyclone was associated with a recycling type of flow in the low-level wavenumber-one asymmetric wind field. This type of wind field allowed a more symmetric distribution of surface momentum and latent heat fluxes, as well as low-level moisture convergence. On the other hand, a weakening or non-intensifying cyclone was associated with a ventilation type of flow in its wavenumber-one field. This type of flow generated asymmetric moisture convergence and momentum flux so that a phase shift developed between them. Cyclones located at the lower latitude (12N) deepened more rapidly than those at the higher latitude (22N) during the early stage.

CONFERENCE PRESENTATION:

Peng, M.S., Jeng, B.-F., and Williams, R.T., "A Numerical Study on Tropical cyclone Intensification," 21st Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, Miami, FL, pp. 326-329, 24-28 April 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Tropical cyclone, vortex, beta-effect, intensity

1995

Faculty Publications and Presentations

METEOROLOGY

JOURNAL PAPERS

Carr, L.E. and Elsberry, R. L., "Monsoonal Interactions Leading to Sudden Tropical Cyclone Track Changes," Monthly Weather Review, Vol. 123, pp. 265-289, 1995.

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